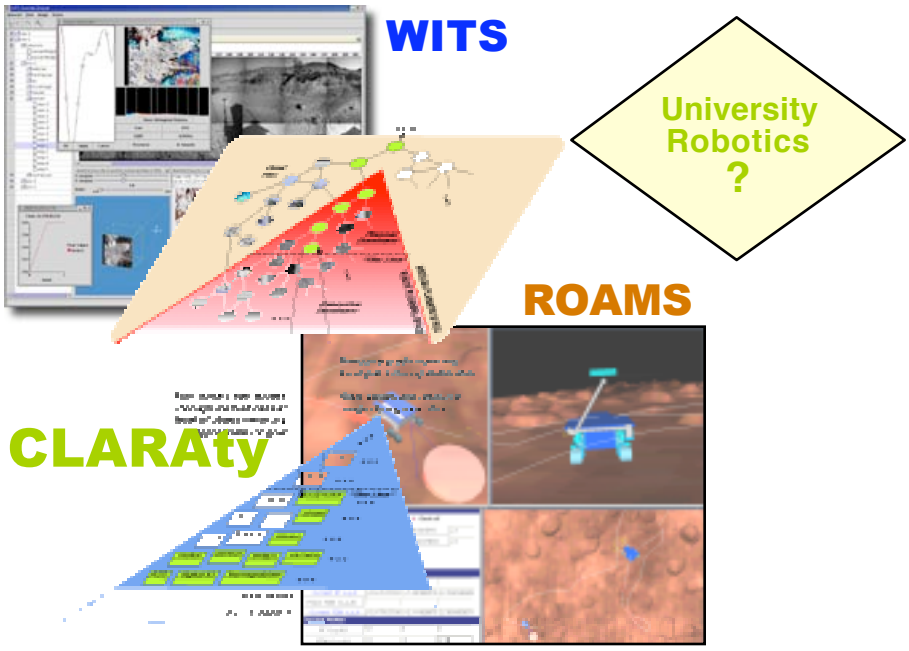
University Robotics Survey and Results

***Appendix B** of*

PLANNING STUDY FOR UNIVERSITY DISTRIBUTION OF NASA ROBOTICS RESEARCH SOFTWARE

Final Report to Mars Technology Program

Dated: August 15, 2003



Prepared by:

Edward Tunstel, Task Manager
and
Gene Chalfant

Mobility Systems Concept Development Section, 348
JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, California 91109

APPENDIX B: UNIVERSITY ROBOTICS (UR) SURVEY

B.1 UR Survey Questions

NASA/JPL University Robotics Researcher Survey

YOUR ROLE IN UNIVERSITY ROBOTICS

1. What is your primary role or affiliation with the robotics lab(s) at your university/college?
   - ○ Laboratory Director
   - ○ Faculty researcher
   - ○ Graduate student researcher
   - ○ Undergraduate student researcher
   - ○ Laboratory Technician
   - ○ other (please specify)

   Do you authorize or specify software tools and packages to be used in your robotics research lab(s)?
   - ○ Yes
   - ○ No

2. What are your functions or responsibilities with respect to robotics research? (check all that apply)
   - ☐ Programmer
   - ☐ Algorithm/Software Design
   - ☐ Mechanical Design/Fabrication
   - ☐ Electronics
   - ☐ Validation/Testing
   - ☐ Theorist
   - ☐ Other (please specify)

   Main topics of research that you are engaged in?
   - ☐ Sensing/Perception
   - ☐ Computer vision
   - ☐ AI Planning/Scheduling
   - ☐ General mobile robotics
   - ☐ Mobile robot navigation/control
   - ☐ Control system synthesis/analysis
   - ☐ Intelligent systems/Autonomy
   - ☐ Manipulation
   - ☐ Kinematics/Dynamics
   - ☐ Behavior-based systems
   - ☐ Multi-robot systems
   - ☐ Other (please specify)

   Please describe the focus of your research in 1 or 2 sentences.

3. To your knowledge, is (has) your university working (worked) on any NASA-sponsored project(?)
   - ○ Yes ○ No

   If YES, which project(s) or research area(s) (and year(s) if known)?

4. Which of the following NASA/JPL robotics software tools are you familiar with? (Check all that apply)
   - ☐ CLARAty (Coupled Layer Architecture for Robotic Autonomy)
   - ☐ WITS (Web Interface for TeleScience)
   - ☐ ROAMS (Rover Analysis, Modeling and Simulation) package
   - ☐ None of the above

DEVELOPMENT TOOLS USED IN YOUR LAB(S)

5. What software development tools are most often used in your labs for robotics research?
   - ☐ Custom written software
   - ☐ 3rd-party software (e.g., "freeware")
   - ☐ Commercial off the shelf (COTS) software

   If COTS and/or 3rd-party software products are used, what are they (e.g., Matlab, LabView, etc)?

6. What are the most common programming languages and operating systems (OS) used by software developers to program robots in your lab(s)? (Check all that apply)
   Programming languages: ☐ C ☐ C++ ☐ Java ☐ LISP ☐ BASIC ☐ other(s)

   Operating Systems: ☐ Microsoft Windows ☐ MacOS ☐ Linux ☐ UNIX ☐ PalmOS ☐ VxWorks ☐ other(s)

7. What computing platforms are most often used in your labs for robotics research?
   ☐ Embedded microcontrollers ☐ Laptops ☐ Single-board PCs ☐ Desktop workstations
   ☐ PDAs (PalmPilot, iPAQ, etc) ☐ PC104 ☐ other(s)

8. What robotic hardware platforms are most often used in your labs for research?
   - ☐ Custom built hardware
   - ☐ Commercial off the shelf (COTS) hardware

   If COTS robot hardware is used, who/what are the vendors/products (e.g., iRobot, ActivMedia, Evolution Robotics, etc)?

GENERAL DEVELOPMENT TOOL NEEDS AND PREFERENCES

9. What are your laboratory's specific needs with respect to externally developed or commercially available robotics SOFTWARE?

10. What would be your expectations regarding support from NASA/JPL of an open-sourced robotics software product?
    Check all that apply and provide supporting comments if any.
    ☐ Phone/e-mail support ☐ Bug tracking and resolution ☐ Extensive documentation ☐ Forums/newsgroups

11. What are your laboratory's specific needs with respect to externally developed or commercially available robotic HARDWARE?

12. **In a robotics development kit including software and hardware, what type of hardware component would be most desirable and useful for your lab's research?**
    - ○ a complete commercial off-the-shelf (COTS) robot with a simple (e.g., serial or USB) control interface
    - ○ a complete COTS robot with interface for downloading executable code
    - ○ hardware parts for complete robot kit requiring assembly with a microcontroller board
    - ○ robot motion control parts (motors and sensors only) requiring assembly with a microcontroller board
    - ○ microcontroller board only
    - ○ other (please specify)

13. **If a robotic hardware item was not included in a NASA software kit, what price range would you consider appropriate for a complete robot system to be purchased by your university for research use?**

INTEREST IN NASA ROBOTICS SOFTWARE

14. **For conducting robotics research, indicate which of the following robotics software features would be of interest to you, and rank its importance for your research (low, medium, or high)?**

☐ Graphical User Interface (GUI) for robot commanding	○ Low	○ Med	○ High
☐ GUI for telemetry receipt, archive, and display	○ Low	○ Med	○ High
☐ Graphical simulation environment (including sensor, robot & terrain models)	○ Low	○ Med	○ High
☐ Locomotion/manipulation support for handling several kinematic configurations	○ Low	○ Med	○ High
☐ Several communication protocols	○ Low	○ Med	○ High
☐ Cross-platform computing compatibility	○ Low	○ Med	○ High
☐ Multiple OS/RTOS support	○ Low	○ Med	○ High
☐ Compatibility with commercial robot hardware	○ Low	○ Med	○ High
☐ Object-oriented design	○ Low	○ Med	○ High
☐ Consistent, standardized Application Programming Interfaces (APIs)	○ Low	○ Med	○ High
☐ Extensibility and customizability	○ Low	○ Med	○ High
☐ Open-source accessibility	○ Low	○ Med	○ High
☐ Libraries of ready-to-use code for selected functional categories:			
Computer Vision library	○ Low	○ Med	○ High
Navigation library	○ Low	○ Med	○ High
Manipulation library	○ Low	○ Med	○ High
Locomotion library	○ Low	○ Med	○ High
Motion Control library	○ Low	○ Med	○ High
Estimation and Filtering library	○ Low	○ Med	○ High
Scientific Data Analysis library	○ Low	○ Med	○ High
Simulation library	○ Low	○ Med	○ High
Math and Transformations library	○ Low	○ Med	○ High
Planning/Scheduling library	○ Low	○ Med	○ High
☐ Other (please specify)	○ Low	○ Med	○ High

15. **Would you be interested in being on a future distribution list of potential university recipients of free NASA-developed robotics software products featuring all or most of the items listed in the previous question?**
    - ○ Yes
    - ○ No

If YES, what would be your primary use for the software? ○ Education ○ Research ○ Both

16. What would be your motivation for using NASA-developed robotics software products? (Check all that apply)
    - ☐ No cost to university
    - ☐ Potential to increase chances of receiving NASA funding or establishing NASA robotics collaborations
    - ☐ Adopt a common framework for development and comparison across different projects in your lab(s)
    - ☐ To avoid having to write low-level code to interface with robotic hardware
    - ☐ Combination of interesting features indicated in Question #14

    List any other motivations:

17. Would you be willing to share software modules that you develop using the NASA robotics software with NASA and the larger user community?
    - ○ Yes
    - ○ No

18. What is the likelihood that your lab would favor using NASA-developed software products to complement or replace your existing tools?
    - ○ High
    - ○ Low

19. Would you be willing to enter into an arrangement where you are supplied robotic hardware for use in your lab in exchange for software contributions to the NASA robotics software user community (e.g., via a student competition in which robotic hardware is awarded as grand prizes)?
    - ○ Yes
    - ○ No

20. Have you surveyed/evaluated the commercial or open source frameworks/architectures currently available for autonomous robotics?
    - ○ Yes
    - ○ No

    If YES, what products have you found of interest?

Many of your counterparts at other US universities are responding to this robotics research survey. If you would like us to share the survey results with you, please provide your e-mail address here:

Submit Query

Reset

B.2 UR Survey Results

The UR survey results are detailed below and categorized according to information about the respondents, the tools used in their labs, and their preferences. Finally, paraphrased excerpts of commentary provided by respondents on the various questions posed by the survey are included.

About the Respondents

Single choice only

43.5% Faculty
27.4% Lab Directors
19.4% Undergraduates
9.7% Graduate students
(Total 100%)

71.0% Lab Directors and Faculty
29.0% Students

85.5% Authorize or specify lab software

17.7% Anonymous responses
82.3% Expressed interest in survey results

Respondent Roles

Sorted by role, multiple roles allowed

79.0% Software (Algorithm) Design
58.1% Programmers
54.8% Theory
37.1% Validation and testing
30.6% Electronics
17.7% Mechanical design & fabrication
6.5% Education (write-in)

Research Areas

72.6% Intelligent Systems/Autonomy
61.3% Mobile Robot Navigation and Control
46.8% Sensing and Perception
46.8% Mobile Robotics
40.3% Behavior-based Robotics
40.3% Multiple Robots
32.3% Vision
32.3% Controls
25.8% AI Planning/Scheduling
24.2% Manipulation
19.4% Kinematics/Dynamics

Past/Present NASA Funding

69.8% indicated knowledge of past/present NASA funded projects at their university

Awareness of NASA Software

Multiple choices allowed

16.1% aware of CLARAty
8.0% aware of WITS
4.8% aware of ROAMS

80.3% unaware of these NASA/JPL robotics software tools

About the University Labs

Software Tools Used

77.4% Custom software
46.8% Third-party software
71.0% Commercial off-the-shelf (COTS) software
- 81.7% of those using COTS use Matlab
- 20.4% of those using COTS use LabView

Language Usage in Labs

Sorted by prevalence, multiple usage allowed

83.9% C++
72.6% C
40.3% Java
35.5% other (Python, Lisp, Basic, Assembly, VHDL, Prolog)

OS Usage in Labs

Sorted by prevalence, multiple usage allowed

66.1% Microsoft Windows
62.9% Linux
24.2% Unix
24.2% other

Computers Used

67.7% Desktops
58.1% Laptops
53.2% Embedded Microcontrollers
32.3% PC boards
29.0% PC104
16.1% PDAs

Robots Used

58.1% Custom built
62.9% Commercial off-the-shelf (COTS)
- 32% of respondents use robots from *ActivMedia Robotics*
- 22% of respondents use robots from *iRobot Corporation*
- <10% of respondents use other COTS robots

About University Preferences

Robot Kit Preferences

Sorted by preference, single choice only

42.4% COTS robot w/simple serial control interface
27.1% COTS robot w/downloadable executable interface
15.3% Hardware parts w/microcontroller board
10.2% Motion control and sensor parts w/microcontroller board
5.1% Microcontroller board only

Software Feature Preferences

(Based on average score: 1 (low) to 3 (high), no answer = 0)
Sorted by score, multiple choices allowed

2.37 Simulation Environment
2.10 Open source
2.00 Extensibility and customizability
1.87 Command GUI
1.74 Consistent APIs
1.55 Object oriented design
1.48 Cross-platform capability
1.42 Several Communication Protocols
1.37 Kinematic Configurations for Locomotion and Manipulation
1.35 Telemetry GUI
1.32 Compatibility with commercial platforms
1.27 Multiple OS support

Libraries:

2.12 Vision
2.00 Navigation
1.84 Simulation
1.68 Locomotion
1.66 Motion control
1.63 Estimation and filtering
1.61 Math and transforms
1.60 Manipulation
1.52 Planning and scheduling
1.40 Scientific analysis

Support Expectations

Multiple choices allowed

69.4% Documentation
59.7% Forums and newsgroups
51.6% Phone/email
43.5% Bug tracking

Primary Reason to use NASA Robotics Software

66.1% Both research and education
19.4% Research only
9.7% Education only
3.2% Not interested in using NASA software

Sharing or Trading Software

98.4% Will share software developments with larger user community
79.7% Would use CLARAty or other NASA robotics software
88.1% Would trade robotics software for robot hardware

Selected Comments

The following reflects various interests & opinions of the respondents.

On simulation needs:

a. A much better simulator for trying out algorithms!!

b. Simulators preferably tied to COTS hardware.

c. Good simulators for general mobile robotics. A rover simulator would be great; in particular, simulations of the robot coupled with specific natural environments (including all sources of uncertainty). Simulations of individual sensor processing routines and other low-level control routines would also be useful.

d. 3D, realistic simulators would be useful

e. Ability to simulate the vehicle in the environment and be able to modify the software to accommodate specific vehicles and sensors

f. Principally robot control/interfacing software, as well as visualization / simulation software.

g. Simulation software for mobile robot navigation that has the capability to simulate different robotic architectures.

h. An easy to use robotics simulation package would be useful. One that can model rigid body dynamics, but also sensors, terrain, etc.

i. A good simulation package with which students could build an entire robot chassis and then test it for stability issues.

j. Access to a dynamic simulator that has models of some oft used robots and sensors. The ability to alter terrain and control the robot through a script or some other easy interface would be fantastic. This simulator would mostly be used for building models, validation and testing. The ability to introduce faults would be cool.

k. Realistic simulation environment allowing behavior design, learning, etc.

l. Modeling, identification, simulation, code generation.

m. Web interface, planner, stereo vision

n. Rover analysis such as ROAMS

o. Mobile robot and UAV simulators.

On open-sourcing, extensibility, and compatibility preferences:

a. Versatile compatibility with different hardware and software.

b. Turn-key systems where all you have to do is modify the configuration file to fit the hardware you are running. Systems like CLARAty are of limited use since the overhead to maintain standardization is a high cost to a Ph.D. student unless they are trying to build an actual NASA compatible system.

c. Externally supplied software must be very flexible and reasonably robust. Most importantly, we need to be able to extend it when it doesn't fit our needs and fix it when it breaks.

d. Portability, adaptability, availability of source code.

e. It is important to have either access to source or extensive information about the structure/algorithms used. It is difficult to use "black box" code within research without comprehending how a tool works.

f. Source code should be available along with a good API. Most developers don't provide all

functionalities of interest to every researcher and so having access to source code is key.

g. Computers, memory, storage space, operating system compatibility

On robot hardware needs:

a. Sensor-rich system; embedded system with LOTS of I/O.
b. Mobile robots with manipulation capability of at least two degrees of freedom, but more would be better.
c. Low-cost small platforms that are easily networked (wireless multi-hop) would be very useful. A rover replica for realistic evaluation of software would be great.
d. CAD sets for NASA rover hardware for comparison to our chassis designs. The ability to make exact copies of Sojourner, FIDO, MER etc, based on CAD files for those chassis would be helpful.
e. Presentation of a well-documented hardware interface.
f. The *Evolution Robotics* robots, I believe, are the next generation of undergraduate/beginning graduate hardware. Because they use COTS laptops, they benefit from the ever-increasing speed and memory and tools.
g. Open architecture systems that allow access to the actuators and sensors directly so that one can implement original control systems. In addition, it would be great to get the dynamic model of the system.
h. A mobile platform with a basic sensor configuration, but one that can easily be layered with custom components (software, HRI, and/or sensors)
i. A small, relatively low cost, front wheel steered robot.
j. High mobility rovers.